(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 676 420 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
07.07.2021 Bulletin 2021/27

(21) Application number: **18768791.8**

(22) Date of filing: **30.08.2018**

(51) Int Cl.:
C23C 28/00 $^{(2006.01)}$ ***C23C 14/06*** $^{(2006.01)}$
C23C 14/32 $^{(2006.01)}$ ***C23C 30/00*** $^{(2006.01)}$

(86) International application number:
PCT/EP2018/073339

(87) International publication number:
WO 2019/043095 (07.03.2019 Gazette 2019/10)

(54) A COATED CUTTING TOOL, METHOD FOR COATING THE CUTTING TOOL AND USE OF COATED CUTTING TOOL

SCHNEIDWERKZEUG, VERFAHREN ZUM HERSTELLEN DESSELBEN UND VERWENDUNG DES SCHNEIDWERKZEUGS

OUTIL DE COUPE REVÊTU, PROCÉDÉ DE REVÊTEMENT D’OUTIL DE COUPE ET UTILISATION D’OUTIL DE COUPE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **30.08.2017 EP 17188637**

(43) Date of publication of application:
08.07.2020 Bulletin 2020/28

(73) Proprietor: **Seco Tools AB**
737 82 Fagersta (SE)

(72) Inventors:
- **FALLQVIST, Mikael**
  77793 Söderbärke (SE)
- **ANDERSSON, Jon**
  723 51 Västerås (SE)

(74) Representative: **Sandvik**
Sandvik Intellectual Property AB
811 81 Sandviken (SE)

(56) References cited:
EP-A1- 1 195 452 **US-A1- 2007 248 424**
US-A1- 2009 120 241 **US-A1- 2009 169 910**

- **C Ducros ET AL: "Multilayered and nanolayered hard nitride thin films for a better yield in micro machining", , 19 May 2008 (2008-05-19), XP055416019, Retrieved from the Internet: URL:http://www.4m-net.org/files/papers/4M2005/02_13/02_13.PDF [retrieved on 2017-10-16]**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Printed by Jouve, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The present invention relates to a coated cutting tool for chip forming metal machining. The invention also relates to a method for coating the cutting tool and to its use in machining of ISO M materials.

BACKGROUND OF THE INVENTION

[0002] Since the mid 1980's, efforts have been made to improve the properties, for example, wear resistance and hence the performance of cutting tool coatings. At that time, the common practice was to coat cutting tools with TiN. However, due to its relatively poor oxidation resistance at elevated temperatures, alloying Al in (Ti,Al)N was suggested and implemented with good results in the mid-1980's. Today (Ti,A1)N based coatings are among the most common hard and protective coating materials used in metal cutting applications. The cubic, BI, structure of (Ti,Al)N, as a monolith layer and/or part of a laminated coating structure, combine attractive mechanical properties such as high hardness and improved temperature and oxidation resistance providing good performance in metal machining applications. The technological benefits of (Ti,A1)N and its excellent physical properties, especially at elevated temperatures, is partly explained in terms of a spinodal decomposition process during which cubic (Ti,A1)N decompose isostructurally into coherent cubic c-AlN- and c-TiN-enriched domains. The combination of elastic properties and a lattice mismatch between coherent c-AlN- and c-TiN-enriched domains leads to significant age hardening during which the hardness of (Ti,A1)N thin layers have shown to increase with between 15% and 20%. At further aging, c-AlN transforms into the thermodynamically stable hexagonal, wurtzite B4 structure, h-AlN resulting in a dual phase structure comprising c-TiN and h-AlN with reduced mechanical properties.

[0003] However, in certain situations, such as machining of work materials giving rise to significant adhesive wear, the present coating solutions are in need of improvement

[0004] US2007/248424A1 discloses a coated cutting tool made of cemented carbide substrate (8), comprising a first base layer (12) of TiN/TiCN/a-A1203 and an outermost PVD layer of Cr (13).

[0005] US2009/120241A1 discloses a cutting tool for machining of wood, comprising a multilayer coating structure consisting of alternating Cr, CrN/CrO and [Cr1-xOx]zXaCbNc layers, deposited by PVD.

OBJECT OF THE INVENTION

[0006] It is an object of the present invention to provide a coated cutting tool with a coating that improves cutting performance by optimizing the interactions between tool and work piece.

[0007] It is also an object of the present invention to provide a method for coating a cutting tool with said coating as well as the use of the cutting tool for machining of ISO M materials.

SUMMARY OF THE INVENTION

[0008] According to a first aspect of the present invention there is provided a coated cutting tool according to claim 1. The coated cutting tool comprises a substrate with a coating having a total thickness of 0.25-30 μm, wherein the coating comprises a first layer and a second layer, and where the first layer is a wear resistant PVD deposited layer having a thickness of 0.2-15 μm, preferably 0.2-10 μm, most preferably 0.5-5 μm, the first layer is arranged between the substrate and the second layer, and wherein the second layer is a Cr (chromium) layer being an outermost layer of the coating.

[0009] According to one embodiment of the invention the thickness of the Cr layer is 0.05-5 μm, preferably 0.05-3 μm.

[0010] According to the invention an x-ray diffraction (XRD) θ-2θ scan, collected on the coated tool using CuKa radiation, comprises body-centered cubic (bcc) structure peaks from a Cr layer.

[0011] According to the invention the Cr layer has a bcc structure with a crystallographic orientation relation of $0.3 < R1 < 1$, preferably $0.4 < R1 < 1$, where $R1 = I_{(110)}/(I_{(110)}+I_{(200)}+I_{(211)})$, and where $I_{(110)}$, $I_{(200)}$, and $I_{(211)}$ are the XRD peak areas as extracted from the pseudo-Voigt peak profile fitting results of θ-2θ scans obtained with CuKα radiation for the bcc structure (110), (200), and (211) Cr layer diffraction peaks, respectively.

[0012] According to an example not according to the claims, the Cr layer has a bcc structure with a crystallographic orientation relation of $0 < R2 < 0.6$, where $R2 = I_{(200)}/(I_{(110)}+I_{(200)}+I_{(211)})$, and where $I_{(110)}$, $I_{(200)}$, and $I_{(211)}$ are the XRD peak areas as extracted from the pseudo-Voigt peak profile fitting results of θ-2θ scans obtained with CuKα radiation for the bcc structure (110), (200), and (211) Cr layer diffraction peaks, respectively.

[0013] According to an example not according to the claims, the Cr layer has a bcc structure with a crystallographic orientation relation of $0 < R3 < 0.2$, where $R3 = I_{(211)}/(I_{(110)}+I_{(200)}+I_{(211)})$, and where $I_{(110)}$, $I_{(200)}$, and $I_{(211)}$ are the XRD peak areas as extracted from the pseudo-Voigt peak profile fitting results of θ-2θ scans obtained with CuKα radiation for the bcc structure (110), (200), and (211) Cr layer diffraction peaks, respectively.

[0014] According to one embodiment of the invention the ratio between the Cr layer thickness and the total coating thickness is between 0.01 and 2, preferably between 0.01 and 1, most preferably between 0.05 and 0.5.

[0015] According to one embodiment of the present invention the first layer has a hardness $H > 20$ GPa, preferably $H > 24$ GPa, most preferably $40 \text{ GPa} > H > 24$ GPa, as measured by nanoindentation experiments.

[0016] According to one embodiment an x-ray diffraction (XRD) θ-2θ scan, collected using CuKα radiation, comprises NaCl type structure peaks from the first layer and body-centered cubic structure peaks from a Cr layer.

[0017] According to one embodiment the ratio, R4, between the XRD peak intensity of the (110) body-centered cubic Cr peak and the XRD peak intensity of the (200) NaCl structure peak originating from the first layer is $0.05 < R4 < 30$, where XRD peak intensity is evaluated as the peak area extracted from the pseudo-Voigt peak profile fitting results of θ-2θ scans obtained with CuKα radiation.

[0018] According an example not according to the claims, the first layer has NaCl type crystal structure with a crystallographic orientation relation of $0.5 < RA \leq 1$, where $RA = IA_{(200)}/(IA_{(200)}+IA_{(111)})$, and where $IA(_{200})$ and $IA_{(111)}$ are the XRD peak areas as extracted from the pseudo-Voigt peak profile fitting results of θ-2θ scans obtained with CuKα radiation for the NaCl structure (200) and (111) the first layer diffraction peaks, respectively.

[0019] According to an example not according to the claims, the peak area ratio RA is $0.6 < RA \leq 1$.

[0020] According to an example not according to the claims, the peak area ratio RA is $0.5 < RA < 0.9$.

[0021] According to an example not according to the claims, the peak area ratio RA is $0.6 < RA < 0.9$.

[0022] According to an example not according to the claims, the peak area ratio RA is $0.5 < RA < 0.8$.

[0023] According to one embodiment of the invention the first layer is a $(Ti_{1-x}Al_x)N_y$ layer with $0.1 < x < 0.7$ and $0.6 < y < 1.1$.

[0024] According to one embodiment of the invention the first layer is a NaCl structure cubic phase c-$(Ti_{1-x}Al_x)N_y$ layer, where $0.1 < x < 0.7$, preferably $0.4 < x < 0.7$, and $0.7 < y < 1.1$.

[0025] According to one embodiment of the invention $0.5 < x < 0.7$.

[0026] According to one embodiment of the invention $0.5 < x < 0.6$.

[0027] According to one embodiment of the invention $0.7 < y < 1.05$.

[0028] According to one embodiment of the present invention, the NaCl structured c-$(Ti_{1-x}Al_x)N_y$ layer optionally contains less than 5 at% each of any of the following: cubic phase c-TiN, cubic phase c-AlN and hexagonal phase h-AlN.

[0029] According to one embodiment of the present invention the first layer is a NaCl structured $(Ti_{1-v}Al_v)N_w / (Ti_{1-a}Si_a)N_b$ nanolaminate with sublayer thickness between 5 and 50 nm, where $0.1 < v < 0.7$, preferably $0.4 < v < 0.7$, $0.7 < w < 1.1$, $0.02 < a < 0.25$, preferably $0.05 < a < 0.15$, and $0.7 < b < 1.1$.

[0030] According to one embodiment of the present invention the first layer is a $(Ti_{1-m}Si_m)N_n$ layer, where $0 \leq m < 0.25$, preferably $0 \leq m < 0.15$, and $0.7 < n < 1.1$.

[0031] According to one embodiment of the present invention the first layer is a $(Cr_{1-c}Al_c)N_d$ layer, where $0.5 < c < 0.9$, preferably $0.5 < c < 0.8$, and $0.7 < d < 1.1$.

[0032] According to one embodiment of the present invention the first layer is a $(Cr_{1-e}Al_e)_2O_3$ layer, where $0.5 < e < 0.9$, preferably $0.5 < e < 0.8$.

[0033] According to one embodiment of the invention the substrate comprises at least one of the following: cemented carbide, cermet, ceramics, steel and cubic boron nitride.

[0034] According to one embodiment of the invention the substrate comprises cemented carbide comprising WC and 4-15 wt% Co.

[0035] According one embodiment the coating may further comprise a third layer other than the first and second layer. The third layer may be a single layer or a multilayer which may be arranged between the substrate and the first layer or between the first and second layer.

[0036] According to a second aspect of the present invention there is provided a method according to claim 16 for producing the coated cutting tool according to claims 1-15, comprising a body and a hard and wear resistant coating by applying PVD (physical vapor deposition) techniques, preferably cathodic arc deposition, the method comprising: growing a Cr layer by using pure Cr cathodes applying an evaporation current between 50 A and 200 A, a gas atmosphere containing pure Ar at a total gas pressure between 1.0 Pa and 7.0 Pa, preferably between 2.0 Pa and 5.0 Pa, and applying a deposition temperature between room temperature and 500 °C. The Cr layer is arranged as an outermost layer of the coating.

[0037] According to one embodiment the above described method comprises applying a negative substrate bias between 0 V and 150 V.

[0038] According to one embodiment of the invention the method further comprises growing a first layer being a $(Ti_{1-x}Al_x)N_y$-1ayer, with $0.1 < x < 0.7$ and $0.7 < y < 1.1$, arranged between the body and the Cr layer, by cathodic arc evaporation with an evaporation current between 50 A and 200 A using composite and/or alloyed (Ti,Al) cathodes, and in a reactive gas atmosphere containing N_2 and optionally mixed with Ar, at a total gas pressure between 1.0 Pa and 7.0 Pa, preferably between 2.5 Pa and 5 Pa, with a negative substrate bias between 0 V and 300 V, preferably between

20 V and 150 V, more preferably between 30 V and 100 V at a temperature between 200 °C and 800 °C, preferably between 300 °C and 600 °C.

[0039] According to one embodiment of invention said first layer is a $(Ti_{1-x}Al_x)N_y$ layer, with $0.1 < x < 0.7$ and $0.7 < y < 1.1$, and is grown using composite and/or alloyed (Ti,Al) cathodes.

[0040] According to a third aspect of the present invention there is provided the use of a coated cutting tool according to any of the above described embodiments in machining of ISO M materials, such as austenitic stainless steels, at cutting speeds of 10 - 400 m/min, preferably 35 - 300 m/min, most preferably 50-200 m/min, with an average feed of 0.05 - 0.5 mm/rev, preferably 0.1 - 0.4 mm/rev, depending on cutting speed and insert geometry.

DEFINITIONS

[0041] The term "cutting tool", as used herein, is intended to denote cutting tools suitable for metal cutting by chip removal, such as turning, milling or drilling. Examples of cutting tools are indexable cutting inserts, solid drills or end mills.

[0042] The term "substrate" as denoted herein should be understood as a body onto which a coating is deposited. Common for cutting tools is that this substrate, for example, a cutting tool insert, may be a solid body or a body comprising a backing body onto which an additional material is placed, either over the cutting edge on the rake face, a so called tipped body, or such that it covers the full rake, a so called full face body. The tipped or full face solutions are frequently used in cutting technologies based on polycrystalline diamond or polycrystalline cubic boron nitride materials.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043] Figure 1 shows x-ray diffractograms for three coatings according to embodiments of the invention. Peaks marked "S" originate from the substrate, peaks marked "A" originate from a first layer, and peaks marked "Cr" originate from the Cr layer.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0044] According to the invention there is provided a coated cutting tool consisting of a substrate and a coating. The coating comprising a first layer and a second layer where the first layer is a wear resistant PVD deposited layer and the second layer is a Cr layer. The Cr layer is arranged as an outermost layer and it has surprisingly been found that the Cr layer gives improved performance in machining. The Cr layer is a PVD deposited layer and has a thickness between 0.05μm and 3μm.

[0045] The average composition of the layers was estimated by energy dispersive spectroscopy (EDS) analysis area using a LEO Ultra 55 scanning electron microscope (SEM) operated at 20 kV and normal incidence to the coated surface equipped with a Thermo Noran EDS. Internal standards and ZAF correction were used for the quantitative analysis. The metal composition was evaluated using a Noran System Six (NSS ver 2) software.

[0046] Coating phase detection and evaluation of preferred crystallographic orientation were performed by XRD using a Bruker AXS D8-advance x-ray diffractometer and Cu $K\alpha$ radiation in Bragg-Brentano configuration. Typically, the detection limit for each phase in a polycrystalline mixed phase materials is less than 5 vol%.

[0047] Figure 1 shows θ-2θ X-ray diffractograms collected from three coatings according to embodiments of the invention. The coating phases were indexed with respect to the JCPDS cards 01-1261 (Cr) and 38-1420 (c-TiAlN), where the latter had to be shifted to match the smaller lattice parameter of c-TiAlN compared to c-TiN. Small amounts, close to or below the detection limit of the diffraction technique, of cubic phase c-TiN, cubic phase c-AlN and hexagonal phase h-AlN phases cannot be ruled out.

[0048] The position and intensity (area) of the crystalline peaks in the XRD diffractograms are determined by fitting a pseudo-Voigt function to each crystalline peak. Additionally, the fitting function contains a linear term to account for residual scattering arising from the background. The XRD data peak fitting was conducted using the Bruker AXS Topas 2.1 software. The resulting peak areas are used to calculate the ratios R1, R2, R3, R4, and RA according to the embodiments of the invention.

Example 1

[0049] Cemented carbide (WC-Co) cutting tools with a range of compositions comprising 6 to 13 wt% Co binder balanced with tungsten carbide (WC) and other carbides of, e.g., titanium, tantalum or niobium as well as various amounts of binder alloying elements such as iron, chromium, nickel, molybdenum or alloys of these elements were used as substrate for the layer depositions by cathodic arc evaporation.

[0050] Before deposition, the cutting tools were cleaned in ultrasonic baths of an alkali solution and alcohol. The system was evacuated to a pressure of less than 2.0×10^{-3} Pa, after which the tools were sputter cleaned with Ar ions.

Then, for coatings 11-110, a $Ti_{0.47}Al_{0.53}N$ layer was deposited at 450 °C using $Ti_{0.45}Al_{0.55}$ cathodes in a reactive N_2 gas atmosphere at a total gas pressure of 4.5 Pa, applying an evaporation arc current of about 150 A and a negative substrate bias of about 50 V. Subsequently, the Cr layers were deposited in separate processes without external heating using Cr cathodes in an Ar atmosphere at a total gas pressure of 4 Pa, applying an evaporation arc current of about 150 A. The substrate bias and thickness was varied for the Cr layer to produce several coatings as shown in Table 1 and for coatings 15-110 an additional Ar etch was introduced before Cr deposition. A reference $Ti_{0.47}Al_{0.53}N$ coating, C1, without Cr layer was also produced at the same time and with same parameters as above. The first layers of coatings I11-I15 and coatings C2-C6 were also deposited by cathodic arc evaporation using similar process parameters, except coatings 115 and C6 in which the chromium aluminium oxide layer was deposited in a pure O_2 atmosphere at a pressure of about 1 Pa.

[0051] The XRD peak intensity ratios as defined in the embodiments of the invention are shown in table 1.

Table 1. Specifications and properties of the coatings.

Coating	**Layer A**			**Cr layer**					R4
Inventive	Composition	Thickness	RA	Thickness	Bias	R1	R2	R3	
I1	$Ti_{0.47}Al_{0.53}N$	2 µm	0.87	0.1 µm	0	0.85	0.01	0.14	0.11
I2	$Ti_{0.47}Al_{0.53}N$	2 µm	0.87	0.3 µm	0	0.87	0.01	0.12	0.68
I3	$Ti_{0.47}Al_{0.53}N$	2 µm	0.83	0.8 µm	0	0.93	0.02	0.05	4.11
I4	$Ti_{0.47}Al_{0.53}N$	2 µm	0.94	2.4 µm	0	0.91	0.04	0.05	19.91
I5	$Ti_{0.47}Al_{0.53}N$	2 µm	0.88	0.8 µm	0	0.53	0.39	0.08	0.71
I6	$Ti_{0.47}Al_{0.53}N$	2 µm	0.87	0.8 µm	10	0.44	0.46	0.10	0.51
I7	$Ti_{0.47}Al_{0.53}N$	2 µm	0.87	0.8 µm	25	0.44	0.50	0.06	0.46
I8	$Ti_{0.47}Al_{0.53}N$	2 µm	0.86	0.8 µm	50	0.46	0.49	0.05	0.43
I9	$Ti_{0.47}Al_{0.53}N$	2 µm	0.88	0.8 µm	100	0.56	0.37	0.07	0.28
I10	$Ti_{0.47}Al_{0.53}N$	2 µm	0.88	0.8 µm	150	0.63	0.30	0.07	0.13
I11	$Ti_{0.38}Al_{0.62}N/Ti_{0.93}Si_{0.07}N$*	2.5 µm	0.86	0.3 µm	0	0.90	0.01	0.09	0.54
I12	$Ti_{0.93}Si_{0.07}N$	2.5 µm	0.97	0.3 µm	0	0.92	0.02	0.06	0.12
I13	TiN	2.5 µm	0.30	0.3 µm	0	0.90	0.01	0.09	1.36
I14	$Cr_{0.31}Al_{0.69}N$	2.5 µm	-**	0.3 µm	0	-**	-**	-**	-**
I15	$(Cr_{0.30}Al_{0.70})_2O_3$	2.5 µm	-***	0.3 µm	0	0.94	0.02	0.04	-***
Comparative	Composition	Thickness	RA	Hardness					
C1	$Ti_{0.47}Al_{0.53}N$	2 µm	0.87	31 GPa					
C2	$Ti_{0.38}Al_{0.62}N/Ti_{0.93}Si_{0.07}N$*	2.5 µm	0.86	29 GPa					
C3	$Ti_{0.93}Si_{0.07}N$	2.5 µm	0.97	30 GPa					
C4	TiN	2.5 µm	0.30	28 GPa					
C5	$Cr_{0.31}Al_{0.69}N$	2.5 µm	-**	30 GPa					
C6	$(Cr_{0.30}Al_{0.70})_2O_3$	2.5 µm	-***	25 GPa					

* Nanolaminate with sublayer thickness about 10 nm.
** Could not be evaluated due to peak overlaps
*** Not evaluated since coating is not in NaCl structure

[0052] The hardness of coating C1, corresponding to the first layer of coatings I1-I10, was evaluated from nanoindentation experiments, after mechanical polishing of the surface, using a UMIS 2000 nanoindentation system with a Berkovich diamond tip and a maximum tip load of 25 mN. The hardness was evaluated from the load-displacement curves using the method of Oliver and Pharr [W.C. Oliver and G.M. Pharr, J. Mater. Res. 7, 1564 (1992)]. An average of about 30 indents was made and a fused silica reference sample was used to check calibration. The hardness of coatings C2-C6, corresponding to the first layers of coatings I11-I15, was also evaluated from nanoindentation experiments, after mechanical polishing of the surface, using a Berkovich diamond tip and a maximum tip load of 4 mN. The hardness was evaluated from the load-displacement curves using the method of Oliver and Pharr [W.C. Oliver and G.M. Pharr, J. Mater. Res. 7, 1564 (1992)]. An average of about 20 indents was made and a fused silica reference sample was used to check calibration. The thus evaluated hardnesses of coatings C1-C6 are shown in Table 1. The standard error was estimated to ± 2 GPa.

Example 2

[0053] WC-Co inserts (ISO geometry TPUN160308) with about 6 wt% Co and coated with inventive coatings 12-14 and comparative coating C1 from Example 1 were tested in turning of 316L. The test was made with repeated 5 mm cutting lengths, using the following data:

Cutting speed: 80 m/min
Feed: 0.2 mm/rev
Depth of cut: 2 mm
Performance criterion: Flank wear

[0054] Table 2 shows a lower flank wear for the inventive coatings relative to the reference comparative coating.

Table 2. Relative flank wear.

Coating	Flank wear
I2	73
I3	77
I4	71
C1	100

Example 3

[0055] WC-Co inserts (ISO geometry TPUN160308) with about 13 wt% Co and coated with coatings I1 and C1 from Example 1 were tested in turning of 316L with the following data:

Cutting speed: 150 m/min
Feed: 0.2 mm/rev
Depth of cut: 3 mm
Performance criterion: Flank wear

[0056] The resulting flank wear of the inventive coating I1 was about 80% of the flank wear of the reference comparative coating.

Example 4

[0057] WC-Co inserts (ISO geometry XOMX120408TR-ME08) with about 13 wt% Co and coated with coatings I1 and C1 from Example 1 were tested in milling of 316L with the following data:

Milling cutter: R417.69-2525.3-12-3A
Cutting speed: 120 m/min
Feed: 0.19 mm/tooth
Depth of cut: 5 mm
ae: 3 mm (12%)
Performance criterion: Flank wear

[0058] The resulting flank wear of the inventive coating I1 was about 65% of the flank wear of the reference comparative coating.

Example 5

[0059] WC-Co inserts (ISO geometry TPUN 160308) with about 6 wt% Co and coated with inventive coatings 12-110 and comparative coating C1 from Example 1 were tested in turning of 316L. The test was made with repeated 20 mm cutting lengths using the following data:

Cutting speed:	80 m/min
Feed:	0.2 mm/rev
Depth of cut:	2 mm
Performance criterion:	Flank wear

[0060] Table 3 shows a lower flank wear for the inventive coatings relative to the reference comparative coating.

Table 3. Relative flank wear.

Coating	Flank wear
I2	91
I3	71
I4	82
I5	89
I6	86
I7	69
I8	78
I9	85
I10	70
C1	100

Example 6

[0061] WC-Co inserts (ISO geometry SNUN120308) with about 6 wt% Co and coated with inventive coatings I1 and I11-I15 and comparative coatings C1-C6 from Example 1 were tested in sliding tests which were performed using a commercially available scratch tester (CSM Instruments Revetest®). In the test, a stainless steel (AISI 316L) pin with a diameter of 10 mm and a polished (R_a=25 nm) hemispherical shaped end surface (radius 5 mm) was loaded against the PVD coated cemented carbide inserts. Sliding tests were performed under dry conditions in ambient air (21-22 °C, 25-26 % RH) using a normal load of 20 N and a relative sliding speed of 10 mm/min. The sliding distance was 10 mm and each test was repeated three times. During testing friction coefficient and acoustic emission were continuously recorded.

[0062] The reduction in measured friction coefficient for each inventive coating compared to the corresponding comparative coating is shown in Table 4. It is clear that the inventive coatings show a significant decrease in friction coefficient compared to their corresponding comparative coating.

Inventive coating	Comparative coating	Friction reduction
I1	C1	40%
I11	C2	18%
I12	C3	16%
I13	C4	19%
I14	C5	22%
I15	C6	17%

Claims

1. A coated cutting tool comprising a substrate with a coating having a total thickness of 0.25-30 μm, wherein the coating comprises a first layer and a second layer, and where the first layer is a wear resistant PVD deposited layer having a thickness of 0.2-15 μm, preferably 0.2-10 μm, most preferably 0.5-5 μm, and the first layer is arranged between the substrate and the second layer, **characterized in that** the second layer is a PVD deposited Cr layer, the Cr layer is an outermost layer of the coating, and that the Cr layer has a body-centered cubic structure with a crystallographic orientation relation of $0.3 < R1 < 1$, where $R1 = I_{(110)}/(I_{(110)}+I_{(200)}+I_{(211)})$, and where $I_{(110)}$, $I_{(200)}$, and $I_{(211)}$ are the XRD peak areas as extracted from the pseudo-Voigt peak profile fitting results of θ-2θ scans

obtained with CuKα radiation for the bcc structure (110), (200), and (211) Cr layer diffraction peaks, respectively.

2. The coated cutting tool according to claim 1, wherein the thickness of the Cr layer is 0.05-5 μm, preferably 0.05-3 μm.

3. The coated cutting tool according to claim 1 or 2, wherein the first layer is a $(Ti_{1-x}Al_x)N_y$ layer with $0.1 < x < 0.7$ and $0.6 < y < 1.1$.

4. The coated cutting tool according to any of the preceding claims, wherein the first layer is a NaCl structure c-$(Ti_{1-x}Al_x)N_y$ layer, where $0.1 < x < 0.7$, and $0.7 < y < 1.1$.

5. The coated cutting tool according to claim 3 or 4, wherein $0.5 < x < 0.6$.

6. The coated cutting tool according to claim 1 or 2, wherein the first layer is a NaCl structured $(Ti_{1-v}Al_v)N_w$ / $(Ti_{1-a}Si_a)N_b$ nanolaminate with sublayer thickness between 5 and 50 nm, where $0.1 < v < 0.7$, preferably $0.4 < v < 0.7$, $0.7 < w < 1.1$, $0.02 < a < 0.25$, preferably $0.05 < a < 0.15$, and $0.7 < b < 1.1$.

7. The coated cutting tool according to claim 1 or 2, wherein the first layer is a $(Ti_{1-m}Si_m)N_n$ layer, where $0 \leq m < 0.25$, preferably $0 \leq m < 0.15$, and $0.7 < n < 1.1$.

8. The coated cutting tool according to claim 1 or 2, wherein the first layer is a $(Cr_{1-c}Al_c)N_d$ layer, where $0.5 < c < 0.9$, preferably $0.5 < c < 0.8$, and $0.7 < d < 1.1$.

9. The coated cutting tool according to claim 1 or 2, wherein the first layer is a $(Cr_{1-e}Al_e)_2O_3$ layer, where $0.5 < e < 0.9$, preferably $0.5 < e < 0.8$.

10. The coated cutting tool according to any of the preceding claims, wherein the ratio between the Cr layer thickness and the total coating thickness is between 0.01 and 2, preferably between 0.01 and 1, most preferably between 0.05 and 0.5.

11. The coated cutting tool according to any of claims 3-5, wherein the first layer has a hardness $H > 20$ GPa, preferably $H > 24$ GPa as evaluated by using the Oliver-Pharr method, and using a Berkovich diamond tip and load of 25 mN for making indentations.

12. The coated cutting tool according to any of claims 6-9, wherein the first layer has a hardness $H > 20$ GPa, preferably $H > 24$ GPa as evaluated by using the Oliver-Pharr method, and using a Berkovich diamond tip and load of 4 mN for making indentations.

13. The coated cutting tool according to any of claims 1-8, or any of claims 10-12, wherein the first layer has a NaCl type structure and the Cr layer has a body-centered cubic structure, the ratio, R4, between the XRD peak intensity of the (110) body-centered cubic Cr peak and the XRD peak intensity of the (200) NaCl structure peak originating from the first layer is $0.05 < R4 < 30$, where XRD peak intensity is evaluated as the peak area extracted from the pseudo-Voigt peak profile fitting results of θ-2θ scans obtained with CuKα radiation.

14. The coated cutting tool according to any of the preceding claims, wherein the substrate comprises at least one of the following: cemented carbide, cermet, ceramics, steel and cubic boron nitride.

15. The coated cutting tool according to claim 14, wherein the cemented carbide comprising WC and 4-15 wt% Co.

16. A method for producing of a coated cutting tool according to any one of claims 1-15, comprising the steps of

- applying a substrate of cemented carbide, cermet, ceramic, steel or cubic boron nitride with a hard and wear resistant coating having a thickness of 0.25-30 μm by means of PVD (physical vapor deposition) techniques, preferably cathodic arc deposition, wherein the coating comprises a first layer and a second layer, the second layer being a Cr layer arranged as an outermost layer of the coating,
- growing the Cr layer by using pure Cr cathodes applying an evaporation current between 50 A and 200 A, a gas atmosphere containing pure Ar at a total gas pressure between 1.0 Pa and 7.0 Pa, preferably between 2.0 Pa and 5.0 Pa, and applying a deposition temperature between room temperature and 500 °C.

17. The method according to claim 16 comprising growing a first layer being a $(Ti_{1-x}Al_x)N_y$-layer, with $0.1 < x < 0.7$ and $0.7 < y < 1.1$, between the substrate and the Cr layer, by cathodic arc evaporation with an evaporation current between 50 A and 200 A using composite and/or alloyed (Ti,Al) cathodes, and in a reactive gas atmosphere containing N_2 and optionally mixed with Ar, at a total gas pressure between 1.0 Pa and 7.0 Pa, preferably between 2.5 Pa and 5 Pa, with a negative substrate bias between 0 V and 300 V, preferably between 20 V and 150 V, more preferably between 30 V and 100 V at a temperature between 200 °C and 800 °C, preferably between 300 °C and 600 °C.

18. Use of a coated cutting tool according to any one of claims 1-15, in machining of ISO M materials at cutting speeds of 10 - 400 m/min and with an average feed of 0.05 - 0.5 mm/rev.

Patentansprüche

1. Beschichtetes Schneidwerkzeug, umfassend ein Substrat mit einer Beschichtung mit einer Gesamtdicke von 0,25-30 μm, wobei die Beschichtung eine erste Schicht und eine zweite Schicht umfasst, und wobei die erste Schicht eine verschleißfeste PVD-abgeschiedene Schicht mit einer Dicke von 0,2-15 μm, vorzugsweise 0,2-10 μm, am meisten bevorzugt 0,5-5 μm, ist, und die erste Schicht zwischen dem Substrat und der zweiten Schicht angeordnet ist, **dadurch gekennzeichnet, dass** die zweite Schicht eine PVDabgeschiedene Cr-Schicht ist, wobei die Cr-Schicht eine äußerste Schicht der Beschichtung ist, und dass die Cr-Schicht eine kubisch-raumzentrierte Struktur mit einem kristallographischen Orientierungsverhältnis von $0{,}3 < R1 < 1$ aufweist, wobei $R1 = I_{(110)}/(I_{(110)}+I_{(200)}+I_{(211)}$, und wobei $I_{(110)}$, $I_{(200)}$ und $I_{(211)}$ die XRD-Peakflächen sind, wie sie aus den Ergebnissen der Pseudo-Voigt-Peakprofilanpassung von θ-2θ Scans , die jeweils mit CuKa-Strahlung für die bcc-Struktur (110), (200) bzw. (211) der Cr-Schicht-Beugungspeaks erhalten wurden, entnommen wurden.

2. Beschichtetes Schneidwerkzeug nach Anspruch 1, wobei die Dicke der Cr-Schicht 0,05-5 μm, vorzugsweise 0,05-3 μm beträgt.

3. Beschichtetes Schneidwerkzeug nach Anspruch 1 oder 2, wobei die erste Schicht eine $(Ti_{1-x}Al_x)N_y$-Schicht mit $0{,}1 < x < 0{,}7$ und $0{,}6 < y < 1{,}1$ ist.

4. Beschichtetes Schneidwerkzeug nach einem der vorhergehenden Ansprüche, wobei die erste Schicht eine NaCl-Struktur c-$(Ti_{1-x}Al_x)N_y$-Schicht ist, wobei $0{,}1 < x < 0{,}7$, und $0{,}7 < y < 1{,}1$.

5. Beschichtetes Schneidwerkzeug nach Anspruch 3 oder 4, wobei $0{,}5 < x < 0{,}6$.

6. Beschichtetes Schneidwerkzeug nach Anspruch 1 oder 2, wobei die erste Schicht ein NaCl-strukturiertes $(Ti_{1-v}Al_v)N_w$ / $(Ti_{1-a}Si_a)N_b$-Nanolaminat mit einer Teilschichtdicke zwischen 5 und 50 nm ist, wobei $0.1 < v < 0{,}7$, vorzugsweise $0{,}4 < v < 0{,}7$, $0{,}7 < w < 1{,}1$, $0{,}02 < a < 0{,}25$, vorzugsweise $0{,}05 < a < 0{,}15$, und $0{,}7 < b < 1{,}1$.

7. Beschichtetes Schneidwerkzeug nach Anspruch 1 oder 2, wobei die erste Schicht eine $(Ti_{1-m}Si_m)N_n$-Schicht ist, wobei $0 \leq m \leq 0{,}25$, vorzugsweise $0 < m < 0{,}15$, und $0{,}7 < n < 1{,}1$.

8. Beschichtetes Schneidwerkzeug nach Anspruch 1 oder 2, wobei die erste Schicht eine $(Cr_{1-c}Al_c)N_d$-Schicht ist, wobei $0{,}5 < c < 0{,}9$, vorzugsweise $0{,}5 < c < 0{,}8$, und $0{,}7 < d < 1{,}1$.

9. Beschichtetes Schneidwerkzeug nach Anspruch 1 oder 2, wobei die erste Schicht eine $(Cr_{1-e}Al_e)_2O_3$-Schicht ist, wobei $0{,}5 < e < 0{,}9$, vorzugsweise $0{,}5 < e < 0{,}8$.

10. Beschichtetes Schneidwerkzeug nach einem der vorhergehenden Ansprüche, wobei das Verhältnis zwischen der Cr-Schichtdicke und der Gesamtschichtdicke zwischen 0,01 und 2, vorzugsweise zwischen 0,01 und 1, besonders bevorzugt zwischen 0,05 und 0,5 liegt.

11. Beschichtetes Schneidwerkzeug nach einem der Ansprüche 3-5, wobei die erste Schicht eine Härte H > 20 GPa, vorzugsweise H > 24 GPa, aufweist, bestimmt unter Verwendung der Oliver-Pharr-Methode und unter Verwendung einer Berkovich-Diamantspitze und einer Belastung von 25 mN zur Herstellung von Vertiefungen.

12. Beschichtetes Schneidwerkzeug nach einem der Ansprüche 6-9, wobei die erste Schicht eine Härte H > 20 GPa, vorzugsweise H > 24 GPa, aufweist, wie unter Verwendung der Oliver-Pharr-Methode und unter Verwendung einer

Berkovich-Diamantspitze und einer Belastung von 4 mN zur Verursachung von Vertiefungen bewertet.

13. Beschichtetes Schneidwerkzeug nach einem der Ansprüche 1-8 oder einem der Ansprüche 10-12, wobei die erste Schicht eine Struktur vom NaCl-Typ und die Cr-Schicht eine kubisch-raumzentrierte Struktur aufweist, wobei das Verhältnis R4 zwischen der XRD-Peak-Intensität des (110)-kubisch-raumzentrierten Cr-Peaks und der XRD-Peak-Intensität des (200)-NaCl-Struktur-Peaks, der von der ersten Schicht stammt, $0,05 < R4 < 30$ ist, wobei die XRD-Peakintensität als die Peakfläche bewertet wird, die aus den Ergebnissen der Pseudo-Voigt-Peakprofilanpassung von θ-2θ Scans entnommen wird, die mit CuKa-Strahlung erhalten wurden.

14. Beschichtetes Schneidwerkzeug nach einem der vorhergehenden Ansprüche, wobei das Substrat mindestens eines der folgenden umfasst: Sinterkarbid, Cermet, Keramik, Stahl und kubisches Bornitrid.

15. Beschichtetes Schneidwerkzeug nach Anspruch 14, wobei das Sinterkarbid WC und 4-15 Gew.-% Co umfasst.

16. Verfahren zur Herstellung eines beschichteten Schneidwerkzeugs nach einem der Ansprüche 1-15, umfassend die Schritte

- Aufbringen eines Substrats aus Hartmetall, Cermet, Keramik, Stahl oder kubischem Bornitrid mit einer harten und verschleißfesten Beschichtung mit einer Dicke von 0,25-30 μm mittels PVD (physical vapor deposition)-Techniken, vorzugsweise kathodischer Lichtbogenabscheidung, wobei die Beschichtung eine erste Schicht und eine zweite Schicht umfasst, wobei die zweite Schicht eine Cr-Schicht ist, die als eine äußerste Schicht der Beschichtung angeordnet ist,
- Aufwachsen der Cr-Schicht unter Verwendung von reinen Cr-Kathoden unter Anwendung eines Verdampfungsstroms zwischen 50 A und 200 A, einer Gasatmosphäre, die reines Ar enthält, bei einem Gesamtgasdruck zwischen 1,0 Pa und 7,0 Pa, vorzugsweise zwischen 2,0 Pa und 5,0 Pa, und unter Anwendung einer Abscheidungstemperatur zwischen Raumtemperatur und 500 °C.

17. Verfahren nach Anspruch 16, umfassend das Aufwachsen einer ersten Schicht, die eine $(Ti_{1-x}Al_x)N_y$-Schicht ist, mit $0,1 < x < 0,7$ und $0,7 < y < 1,1$, zwischen dem Substrat und der Cr-Schicht, durch kathodisches Lichtbogenverdampfen mit einem Verdampfungsstrom zwischen 50 A und 200 A unter Verwendung von Verbund- und/oder legierten (Ti,Al)-Kathoden und in einer reaktiven Gasatmosphäre, die N_2 enthält und gegebenenfalls mit Ar gemischt ist, bei einem Gesamtgasdruck zwischen 1,0 Pa und 7,0 Pa, vorzugsweise zwischen 2,5 Pa und 5 Pa, mit einer negativen Substratvorspannung zwischen 0 V und 300 V, vorzugsweise zwischen 20 V und 150 V, besonders bevorzugt zwischen 30 V und 100 V bei einer Temperatur zwischen 200 °C und 800 °C, vorzugsweise zwischen 300 °C und 600 °C.

18. Verwendung eines beschichteten Schneidwerkzeugs nach einem der Ansprüche 1-15 bei der Bearbeitung von ISO M-Materialien bei Schneidgeschwindigkeiten von 10-400 m/min und einem mittleren Vorschub von 0,05-0,5 mm/Umdrehung.

Revendications

1. Outil de coupe revêtu comprenant un substrat avec un revêtement présentant une épaisseur totale de 0,25 à 30 μm, où le revêtement comprend une première couche et une seconde couche, et où la première couche est une couche déposée par PVD résistant à l'usure présentant une épaisseur de 0,2 à 15 μm, de préférence de 0,2 à 10 μm, de façon la plus préférée de 0,5 à 5 μm, et la première couche est agencée entre le substrat et la seconde couche, **caractérisé en ce que** la seconde couche est une couche de Cr déposée par PVD, la couche de Cr est une couche la plus à l'extérieur du revêtement, et **en ce que** la couche de Cr présente une structure cubique centrée avec une relation d'orientation cristallographique de $0,3 < R1 < 1$, où $R1 = I_{(110)}/(I_{(110)}+I_{(200)}+I_{(211)})$, et où $I_{(110)}$, $I_{(200)}$ et $I_{(211)}$ sont les aires de pics DRX telles qu'extraites des résultats de régression de profil de pic de pseudo-fonction de Voigt de scans de θ à 2θ obtenus avec un rayonnement CuKα pour les pics de diffraction de couche de Cr à structure cc (110), (200), et (211), respectivement.

2. Outil de coupe revêtu selon la revendication 1, dans lequel l'épaisseur de la couche de Cr va de 0,05 à 5 μm, de préférence de 0,05 à 3 μm.

3. Outil de coupe revêtu selon la revendication 1 ou 2, dans lequel la première couche est une couche de $(Ti_{1-x}Al_x)N_y$

avec $0,1 < x < 0,7$ et $0,6 < y < 1,1$.

4. Outil de coupe revêtu selon l'une quelconque des revendications précédentes, dans lequel la première couche est une couche de c-$(Ti_{1-x}Al_x)N_y$ à structure NaCl avec $0,1 < x < 0,7$, et $0,7 < y < 1,1$.

5. Outil de coupe revêtu selon la revendication 3 ou 4, où $0,5 < x < 0,6$.

6. Outil de coupe revêtu selon la revendication 1 ou 2, dans lequel la première couche est un nanostratifié de $(Ti_{1-v}Al_v)N_w$ / $(Ti_{1-a}Si_a)N_b$ à structure NaCl présentant une épaisseur de sous-couche entre 5 et 50 nm, où $0,1 < v < 0,7$, de préférence $0,4 < v < 0,7$, $0,7 < w < 1,1$, $0,02 < a < 0,25$, de préférence $0,05 < a < 0,15$, et $0,7 < b < 1,1$.

7. Outil de coupe revêtu selon la revendication 1 ou 2, dans lequel la première couche est une couche de $(Ti_{1-m}Si_m)N_n$, où $0 \leq m < 0,25$, de préférence $0 \leq m < 0,15$, et $0,7 < n < 1,1$.

8. Outil de coupe revêtu selon la revendication 1 ou 2, dans lequel la première couche est une couche de $(Cr_{1-c}Al_c)N_d$, où $0,5 < c < 0,9$, de préférence $0,5 < c < 0,8$, et $0,7 < d < 1,1$.

9. Outil de coupe revêtu selon la revendication 1 ou 2, dans lequel la première couche est une couche de $(Cr_{1-e}Al_e)_2O_3$, où $0,5 < e < 0,9$, de préférence $0,5 < e < 0,8$.

10. Outil de coupe revêtu selon l'une quelconque des revendications précédentes, dans lequel le rapport entre l'épaisseur de couche de Cr et l'épaisseur de revêtement totale est entre 0,01 et 2, de préférence entre 0,01 et 1, de façon la plus préférée entre 0,05 et 0,5.

11. Outil de coupe revêtu selon l'une quelconque des revendications 3 à 5, dans lequel la première couche présente une dureté $H > 20$ GPa, de préférence $H > 24$ GPa telle qu'évaluée en appliquant la méthode d'Oliver et Pharr, et en utilisant une pointe en diamant de Berkovich et une charge de 25 mN pour pratiquer des indentations.

12. Outil de coupe revêtu selon l'une quelconque des revendications 6 à 9, dans lequel la première couche présente une dureté $H > 20$ GPa, de préférence $H > 24$ GPa telle qu'évaluée en appliquant la méthode d'Oliver et Pharr, et en utilisant une pointe en diamant de Berkovich et une charge de 4 mN pour pratiquer des indentations.

13. Outil de coupe revêtu selon l'une quelconque des revendications 1 à 8, ou selon l'une quelconque des revendications 10 à 12, dans lequel la première couche présente une structure de type NaCl et la couche de Cr présente une structure cubique centrée, le rapport, R4, entre l'intensité de pic DRX du pic de Cr cubique centré (110) et l'intensité de pic DRX du pic de structure NaCl (200) provenant de la première couche est de $0,05 < R4 < 30$, où l'intensité de pic DRX est évaluée comme l'aire de pic extraite des résultats de régression de profil de pic de pseudo-fonction de Voigt de scans de θ à 2θ obtenus avec un rayonnement $CuK\alpha$.

14. Outil de coupe revêtu selon l'une quelconque des revendications précédentes, dans lequel le substrat comprend au moins l'un des éléments suivants : carbure cémenté, cermet, céramique, acier et nitrure de bore cubique.

15. Outil de coupe revêtu selon la revendication 14, le carbure cémenté comprenant du WC et de 4 à 15 % en poids de Co.

16. Procédé de production d'un outil de coupe revêtu selon l'une quelconque des revendications 1 à 15, comprenant les étapes consistant à

- appliquer sur un substrat de carbure cémenté, de cermet, de céramique, d'acier ou de nitrure de bore cubique, un revêtement dur et résistant à l'usure présentant une épaisseur de 0,25 à 30 μm au moyen de techniques PVD (dépôt physique en phase vapeur), de préférence par dépôt à l'arc cathodique, où le revêtement comprend une première couche et une seconde couche, la seconde couche étant une couche de Cr agencée comme une couche la plus à l'extérieur du revêtement,
- faire croître la couche de Cr en utilisant des cathodes de Cr pur en appliquant un courant d'évaporation entre 50 A et 200 A, une atmosphère gazeuse contenant de l'Ar pur à une pression gazeuse totale entre 1,0 Pa et 7,0 Pa, de préférence entre 2,0 Pa et 5,0 Pa, et en appliquant une température de dépôt entre la température ambiante et 500 °C.

17. Procédé selon la revendication 16, comprenant le fait de faire croître une première couche qui est une couche de

$(Ti_{1-x}Al_x)N_y$, avec $0,1 < x < 0,7$ et $0,7 < y < 1,1$, entre le substrat et la couche de Cr, par évaporation à l'arc cathodique avec un courant d'évaporation entre 50 A et 200 A en utilisant des cathodes de (Ti/Al) composites et/ou alliées, et dans une atmosphère gazeuse réactive contenant du N2 et optionnellement mélangée à de l'Ar, à une pression gazeuse totale entre 1,0 Pa et 7,0 Pa, de préférence entre 2,5 Pa et 5 Pa, avec une polarisation de substrat négative entre 0 V et 300 V, de préférence entre 20 V et 150 V, de façon davantage préférée entre 30 V et 100 V à une température entre 200 °C et 800 °C, de préférence entre 300 °C et 600 °C.

18. Utilisation d'un outil de coupe revêtu selon l'une quelconque des revendications 1 à 15, dans le cadre d'un usinage de matériaux ISO M à des vitesses de coupe de 10 à 400 m/min et selon une avance moyenne de 0,05 à 0,5 mm/tr.

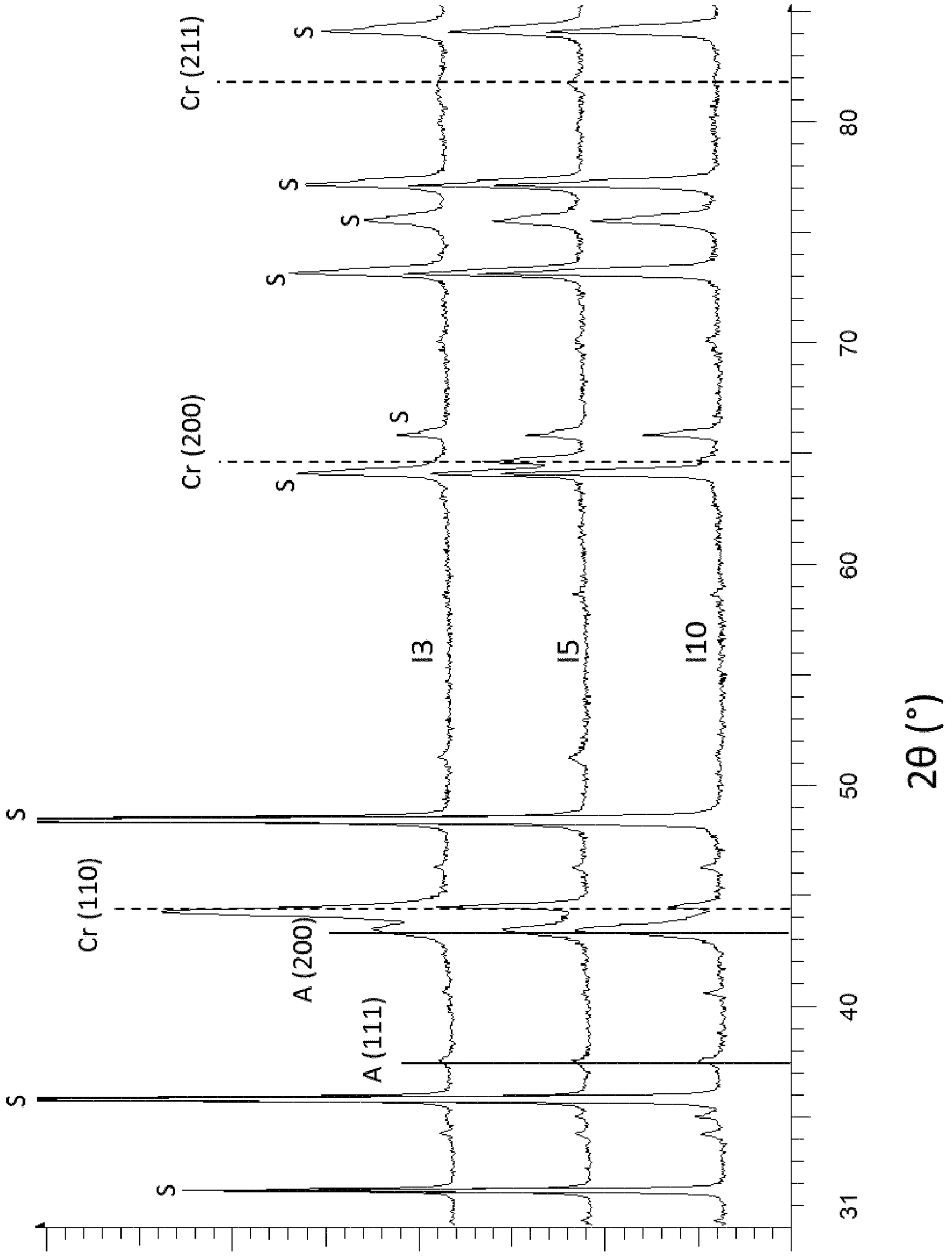
S
S
A (111)
A (200)
Cr (110)
S
I3
I5
I10
S
Cr (200)
S
S
S
S
Cr (211)
S
31
40
50
60
70
80
2θ (°)

Fig. 1

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 2007248424 A1 **[0004]**
- US 2009120241 A1 **[0005]**

Non-patent literature cited in the description

- **W.C. OLIVER ; G.M. PHARR.** *J. Mater. Res.,* 1992, vol. 7, 1564 **[0052]**